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THE PANAMA CANAL—SOME OBJECTIONS TO A SEA-LEVEL PROJECT.

BY BRIGADIER-GENERAL PETER C. HAINS, U.S.A.

UNTIL within a few months, it was generally supposed that it had been definitely decided that the canal to be built at Panama to connect the Atlantic and Pacific oceans was to be a canal with locks. Recently, the discussion of the sea-level project has been revived and the desirability of carrying out the project of a canal with locks questioned. Under the circumstances, it will not be out of place to offer a few reasons why this is not good policy.

No one would think of questioning the great merits of a sea-level canal over one with locks, and yet there is considerable misunderstanding in respect to what a sea-level canal at Panama would be. To the ordinary man, a sea-level canal is one through which vessels may pass without obstruction of any kind. It is generally understood to be an open cut with no locks, like the Suez Canal connecting the Mediterranean with the Red Sea, or the St. Clair Canal connecting Lake Huron with Lake St. Clair. The construction of such a sea-level canal at Panama is not feasible.

At Panama, the south end of the canal, the rise and fall of tide is about 20 feet. At Colon, the other end, the rise and fall is only about one foot; the mean level of the two oceans being precisely the same. The level of the ocean at Panama, therefore, is 10 feet higher at high tide and 10 feet lower at low tide than it is at Colon, and this is the case twice every day. The currents, therefore, in such a sea-level canal would, for most of the time, be so swift that large ships could not be handled with safety. The only way of obviating the difficulties arising from these conditions is to provide a tide-lock. The mean level may then be maintained between the lock and the Atlantic Ocean, and the level on the Pacific side may be allowed to fluctuate 10 feet above and 10 feet below. The difference, therefore, between a *sea-level canal* and a *lock canal at Panama* is, that the former requires one lock and the latter requires several.

A canal with only one lock is, of course, better than one with several, but how much better? Is it worth $100,000,000 more and ten years delay? If the canal is to benefit the country as greatly as is sometimes claimed, many hundred millions more would be lost because of delay alone. The canal should be opened to navigation at the earliest time practicable. Unnecessary delay will be a misfortune. A delay of ten years will be a calamity.

Suppose some of the prophets fall short in their estimate of the value of the canal. Many people think it will not pay as an investment. It certainly is not probable that it will pay in the first few years after it is open to navigation. Canals do not, as a rule, pay at first. It takes time to establish new lines of traffic. The Suez Canal did not pay at first; and there is every reason to believe that the Panama Canal will follow the ordinary rule.

The construction of a lock canal at Panama will not prevent its ultimate conversion into a sea-level canal should the future demands of commerce require that; while the additional cost, due to the extra cost of excavation, while the canal is in use, can be borne so much better after it shall have been demonstrated that a sea-level canal is necessary. The canal is chiefly for the benefit of future generations. Why not put part of the burden of cost upon them? Why spend $100,000,000 now and delay construction ten years when, possibly, nay probably, a sea-level canal will *never* be required? The passage of a ship through one lock is only in degree less objectionable than its passage through five.

The fear seems to be that, as ships are growing larger and larger, it will only be a comparatively short time when they will be too large to pass through locks that to-day would be quite large enough. It is true that the size of ships has increased with great rapidity in the last few years, and it may be that the limit has not yet been reached. But the locks can be increased in size and the canal otherwise enlarged when the demands of commerce require it. The locks should, of course, be built in duplicate, and when it is found that they are too small, if it ever should be, one at a time could be enlarged or new ones built to take their place. That is the history of all lock canals. At first, for economical reasons, the locks are built to accommodate the commerce of the day, or what may be reasonably anticipated in the near future. Afterward, when the growth in the size of vessels demands it, new and larger ones are added. The argument against a lock canal is not applicable at Panama, for the reason that it can never be a canal without locks. It must have tide-locks.

The difficulties of passing ships through locks are much exaggerated. All ships have to be docked for repairs, and to dock a ship is a much more difficult operation than to pass one through a lock. With care, there need be no difficulty in locking a ship through a canal. The Manchester Canal is a *ship-canal with locks.* Its commerce is steadily growing. The *Soo Canal is a canal with locks.* The commerce passing through it annually is something enormous. The Kanawha River has been made navigable in its low stages by building locks and dams, converting it practically into a *lock canal.* The Ohio and other rivers in the United States are being treated in the same way.

It has been estimated that the water-supply of the Chagres River is sufficient for a traffic of 40,000,000 tons annually, over three times the tonnage that now passes through the Suez Canal and 10,000,000 tons more than was passed through the Soo Canal during the past year. Who can tell that the tonnage through the Panama Canal will ever reach such figures? When it does, the question of cost of conversion will be of secondary importance.

It is confidently believed that a sea-level canal at Panama will never become necessary, that a canal with locks will furnish all the facilities for vessels of the largest tonnage and greatest draft that will ever come into use; but in view of the uncertain possibilities of future commercial conditions, the canal may be built with a view to its ultimate conversion, if the necessity should ever arise. This can be done without increasing the first cost. In fact, the first cost may be somewhat reduced. Retaining walls in the Culebra Cut were recommended by the Isthmian Canal Commission; but, if the canal be built with a view to its possible conversion into a sea-level canal, these walls should be omitted, as they would interfere with that conversion. The cost of these masonry walls was estimated at about $9,000,000. Their necessity was not fully demonstrated, but in the interests of safety from caving slopes it was thought best to build them. The saving of $9,000,000 by omitting them would go a long way toward defraying the extra cost of the sea-level canal, if it ever became advisable. The Technical Commission did not think such retaining walls necessary and did not recommend them; from which it will be seen that engineers, who may agree as to their utility, are not of one mind as to their necessity.

In 1887, when he was Chief Engineer of the Canal, Mr. Bunau-Varilla suggested a plan for converting a lock canal into a sea-level one. The plan was gotten up for the benefit of the stockholders of the old Panama Canal Company before it became bankrupt, and had in view the opening of the canal to navigation at the earliest practicable date with locks, and at the same time retaining the idea so tenaciously held by the followers of Mr. De Lesseps of ultimately making it a sea-level canal. It involved some changes in the ordinary arrangement of the lock-gates and in the depth of canal in their immediate vicinity, and provided for excavating, while the canal was being used for navigation, by increments of about five feet. The plan is practicable, and the additional expense for the modifications in the locks should not exceed about $1,000,000. The expense of excavating would, of course, be considerably increased. To carry out his plan, or indeed any plan of conversion, it would be necessary to construct a dam at Alhajuela or Gamboa and create a reservoir in the upper valley of the Chagres, in which the freshet discharge could be impounded and from which it could be discharged into the Atlantic or Pacific ocean.

If the canal be built with locks, more time will be afforded for working out the best solution of the sea-level project. It is not a simple problem of "digging dirt," as some suppose. It involves the study of the most intricate hydraulic problems in taking care of the floods of the Chagres River and the best way of dealing with the Culebra Cut. The first Canal Company was wrecked because it failed to fully investigate these problems in the beginning. It is all well enough to talk about the scandals and extravagances of that company; but, making due allowance for these, there was still left sufficient money to build a canal with locks, if the magnitude of the problems had been fully appreciated and thorough investigation made before the work was started. The new Commission should not be hurried. The problem is too important. It is known now, though it was not in the beginning, that the Chagres River in high freshets may discharge as much as 50,000 or 60,000 cubic feet of water per second at Alhajuela; that at Gamboa, near where the river strikes the line of the canal, it may be about 20 or 30 per cent. more. This amount of water cannot be taken into the canal, if it be of reasonable dimensions, without destroying it. To divert this water into the Atlantic or Pacific ocean, will involve passing it through a tunnel several miles, at least, in length. What must be the size of a tunnel to safely carry 60,000, or possibly 70,000, cubic feet of water per second? To make thorough surveys and studies for the determination of the best method of disposing of this amount of water in that country will take time and the best of engineering talent. The latter may be in the possession of the Government now, but the former can only be had by delay.

When Congress passed the Act, approved June 28, 1902, providing for the construction of an interoceanic canal to connect the Atlantic with the Pacific ocean, it failed to specify in definite terms what project it intended to have executed. In fact, it is doubtful whether or not Congress had any definite project in view, except that the canal was to have "sufficient capacity and depth" to afford passage for the largest vessels now in use and such as may be reasonably anticipated. A canal may, if built according to one project, cost $100,000,000, or, if built according to some other project, $200,000,000, or $300,000,000. Did Congress intend to leave the question of plan and, therefore, of cost to be determined afterward; or did it intend that the canal should be built in accordance with some definite project? This is a question of immense importance; for, if Congress intended the appropriation for any definite project, the appropriation is available for that project, and that alone.

That the omission to state in specific terms the project it had in mind was an oversight on the part of Congress, would seem to be an unsupportable theory. Such an important matter could scarcely have been overlooked, in view of the long and tedious debates that preceded the enactment. Either a definite project was intended, or the project was purposely left open for the President to determine after a new Commission was appointed. The law provides for a new Commission to construct the canal under the direction of the President, and it may have been intended to leave to him the determination of the project, subject only to the limitation that it "should afford convenient passage for vessels of the largest tonnage and greatest draft that may be reasonably anticipated." If he is to be held responsible for the faithful execution of the canal project, it is only reasonable to give him a wise discretion in regard to it.

The project of the Isthmian Canal Commission was for a canal with locks. The general width of the bottom of the canal was to be 150 feet, widened in the bends according to the degree of curvature. The summit level was to be carried through the "divide cut" at an elevation that would fluctuate from 82 to 92.5 feet above mean sea-level. A single lake or reservoir was to be formed by the construction of a dam at Bohio, the water of the Chagres River was to be received into this lake and the surplus discharged over a spillway at Gigante, and thence led by diversion channels into the Atlantic Ocean. Harbors were provided at each end of the canal.

The estimated cost of the project was $144,233,358. The amount appropriated and pledged, exclusive of the $40,000,000 to be paid the new Panama Canal Company for their property, privileges, etc., was $145,000,000. It will thus be seen that the estimate of the Commission and the amount appropriated and pledged were almost exactly the same, Congress merely adopting a round sum, in place of the estimate of the Commission which gave the exact figures as they appeared in summing up the grand total.

The same similarity is seen in the figures for the Nicaragua route. The estimate of the Commission for the canal on that route was $189,864,052. The amount appropriated and pledged by the Act of June 28, 1902, was $190,000,000, a round sum, as in the other case.

The wording of the first part of Section 5 is "that the sum of $10,000,000 is hereby appropriated out of any money in the Treasury not otherwise appropriated toward the *project herein contemplated* by either route." This would seem to indicate that Congress contemplated a definite project, though none is specifically mentioned. It is quite possible, however, that Congress may have used the term "project" in its most general sense, meaning a canal project of certain dimensions, and not a definite project. The condition that the canal is to be "of sufficient capacity to accommodate vessels of the largest tonnage that may be anticipated" would seem to imply that just what would be sufficient was not very clearly defined in the mind of Congress. The Isthmian Canal Commission offered the project of a canal with locks of specified dimensions, which would meet the prospective demands of commerce. Congress did not accept in terms the project of that Commission, nor its dimensions, but seems to have left the matter in such shape that any or all of these might be varied.

One of two things is evident: either Congress intended to adopt the project of the Isthmian Canal Commission or to leave the definite determination of it to the President, subject to the single limitation that the canal shall be large enough to accommodate the largest vessels now in use or such as may be reasonably anticipated.

There are several modifications which are not radical in their nature, do not change any of the dimensions of the canal and actually effect a reduction in cost, which it is believed can be made to advantage under either view of the law.

These modifications are as follows:

First, a reduction in the height of the summit level to about 65 feet above mean tide;

Second, the construction of a dam at Alhajuela or Gamboa, so as to create a reservoir or lake in the upper valley of the Chagres to supply water for the canal in the dry season and regulate the freshets in the wet;

Third, the omission of the masonry retaining walls along the Culebra Cut.

Several important advantages result from a reduction in the height of the summit level. During the dry season which lasts about three months, the flow of the Chagres River is not sufficient to supply the needs of navigation and the losses due to lockage, evaporation, etc. This deficiency is estimated, for a traffic of 10,000,000 tons annually, to be about 3,000 million cubic feet. If there be only one lake, as in the project of the Isthmian Canal Commission, this amount of water must be stored up in it to supply the deficiency. This corresponds to a depth of 3.4 feet in the lake. The latter will, therefore, be drawn down that amount in the dry season, and consequently, the entire summit level must be excavated that additional depth. If, however, this deficiency be supplied from outside sources, as it would be from a reservoir or lake in the upper valley of the Chagres, the level of the summit could be maintained at the normal without fluctuation.

But the great advantage of the two-lake system consists in the satisfactory solution it gives to the problem of regulating the Chagres River in times of floods. At Bohio, a distance of about twenty miles from the sea, measured on the line of the canal, the discharge has been found to be about double what it is at Alhajuela. It will be readily understood that, if all the water that falls into the basin above Alhajuela could be shut off, the violence of the flood would be reduced one-half; if one-third, its violence would be reduced one-third. The capacity of the upper lake may be roughly estimated by considering it as an inverted truncated cone, with a base of 11.5 square miles and a height of 40 feet, which is within limits. This would give a capacity of about 12,000 million cubic feet. The maximum discharge of the Chagres at Bohio during the largest freshet known was estimated at about 112,000 cubic feet per second for 48 hours. One-half of this is 56,000 cubic feet, which represents the amount that passed Alhajuela. If this had all been held back during the 48 hours, it would amount to 9,000 million cubic feet. It will thus be seen that the entire discharge at Alhajuela could have been held back until the violence of the flood was past, if there had been such a reservoir. But there is no need for holding it all back, because about one-half of what passes Alhajuela could be allowed to run into the lower lake during the continuance of the freshet, without damage to the work and with no inconvenience to commerce. The total amount received in Lake Bohio under this arrangement would have been about 84,000 cubic feet per second. If one-half of this amount were discharged over the spillway, the accretions in Lake Bohio would be represented by 42,000 cubic feet per second. The fluctuations in the level of the lake under these conditions would be only about five feet.

It is understood that recently a good site for a dam has been found near Gamboa, much nearer the canal than Alhajuela. If this be so, the problem of regulation is still further simplified, for the upper reservoir could be very much enlarged by the construction of the dam at that site.

The spillway recommended by the Isthmian Canal Commission is automatic in its action. The spillway to be constructed under the two-lake project is to be provided with gates. The Stoney system is used on the Manchester Ship-Canal and on the Chicago Drainage Canal, and would answer the purpose here. The automatic system is simpler; but, by means of the gates, the discharge is entirely within control, and this, under some circumstances, might be a matter of considerable consequence. The gate system would be the cheaper in first cost, on account of the shorter length of the spillway and the smaller amount of excavation required to convey the discharged water to the sea; but no estimate has been made of these items, the cost of operation being considered an offset.

By lowering the summit level to about sixty-five feet and creating a second lake or reservoir in the valley of the upper part of the Chagres, the lift of four of the locks can be reduced about eleven feet each. Instead of a maximum lift of 46 feet, they will have a maximum lift of only 35 feet each. This is a great advantage. For, though there is little difference so far as the ship is concerned, whether it is lifted 35 feet or 46 feet, after it has once entered the lock, it is not so in respect to the lock itself. A ship of 30,000 tons striking the lock wall, even though it be moving slowly, will set up strains, the effects of which cannot be calculated. Theoretically, there is no more trouble in designing a lock of 46 feet lift than there is in designing one of 35; but, practically, there is difficulty in constructing and operating it. All the defects of workmanship and material are exaggerated as the work is enlarged; and, if anything gets out of order, it is more difficult to repair, and the danger of something getting out of order is greater. The reduction in the lift of the locks will effect a considerable saving in their cost. No attempt has been made to estimate the exact saving, but an approximate estimate gives a saving of not less than 15 per cent. in masonry, besides a reduction in other items. As the four locks are estimated to cost about $20,000,000, it is safe to say that the reduction in cost will be about $3,000,000.

The lowering of the summit level eliminates one of the most difficult problems in connection with the canal project, viz., the construction of a core-wall in the Bohio dam. This core-wall was adopted by the Isthmian Canal Commission, partly in the interest of safety and partly to prevent seepage under it. The dam proposed was an earthen one, but the sandy clay foundation, on which it was to rest, was underlaid by varying strata of sand and clay; and, inasmuch as it could not be determined with certainty whether or not the sand strata extended to the surface on either or both sides of the dam, the only safe course was to assume that they did, and to provide for cutting off seepage by a core-wall of masonry extending to the rock. The rock was found in places to be at a depth of about 128 feet below sea-level, necessitating the use of pneumatic caissons to reach it. The difficulties attending the construction of this core-wall were fully appreciated, but the dam so built was regarded as perfectly safe, and all seepage, whether it might prove to be great or small, would be cut off. It is reported that recent borings at the site of the Bohio dam have shown that the rock in some places is over 160 feet below tide. If this be so, the masonry core-wall may be considered as impracticable, for pneumatic caissons could not be used to that great depth. Consequently, the dam must be built without a masonry core-wall. Under these circumstances, the reduction in height becomes almost imperative.

A masonry core-wall in a low dam is not a necessity. The ample water-supply which the upper lake furnishes will more than replace many times over any loss due to seepage, whether it be relatively great or small. There may, in fact, be no seepage at all. The irregular sandy strata may only be pockets, and this is the most probable hypothesis, judging from the irregularity of the thickness of the strata as determined by the borings. Ordinarily, when a dam is intended to store up a supply of water for a city or for irrigating purposes, the loss due to seepage may be an important matter; but, in this case, it need not be considered.

In respect to time of completion, the single-lake project has the advantage. The Culebra Cut is the feature that determines the time of completing the canal under any plan. It will require about a year to dig the extra depth for the lower level. But, on the other hand, if the canal should ever be converted into a sea-level canal, there will be just so much less excavation to accomplish it. It is not the quantity of material to be removed that gives the Culebra Cut its importance; it is the fact that the work is so concentrated that a large force cannot work there to advantage. Moreover, the excavated material cannot be deposited near by.

It must be hauled to safe dumping-grounds where it will not be washed back into the canal. Already, the low places in the near vicinity of the Cut have been filled up, and now it is necessary to haul the excavated material several miles. The heavy part of the Cut is but little more than a mile in length. To fill this space with contractors and contractors' men would not facilitate work, it would retard it. One would as soon think of crowding workmen at the head of a tunnel. Only a certain number of men and machines can be worked to advantage, and that number is comparatively small.

The Isthmian Canal Commission, as well as the Technical Commission, proposed to give to the slopes of the Culebra Cut an inclination of 45 degrees from base to top, cut like steps in risers and treads, the former to be about twenty feet high, the latter about fifteen feet wide. No special provision was made for drainage. The treads would thus naturally drain to the front, and the rain falling on them would pour over and down the slope of the riser. The water falling on the upper step would be added to that falling on the one below, and this double amount to the one below it. The quantity would thus be multiplied by the number of steps passed. If one inch of rain falls on the upper tread, about two inches will fall on the second, three inches on the third, and so on to the bottom. If there should be as many as ten steps, corresponding to a cut 200 feet deep, and two inches of rain per hour falling, the amount of water on the last step would be 20 inches per hour. Such a rainfall, which is not unusual in that climate, would cause quite a torrent to pour over the lower risers. Gullies would form on the lower risers, even though they should not on the upper ones, and the material, unless it be exceedingly stiff, or protected, would be washed into the canal, and the stability of the slope endangered. To overcome this, it is proposed to make the risers vertical, and drain the treads to the rear, conveying the water falling on them into the canal by pipes at suitable distances. By this system of drainage, erosion will be reduced to a minimum. The stiff material of which the hill is composed ought then to stand without much tendency to wear from the effects of the weather. Slopes treated in this way, even where the material is easily eroded, retain their shape with a considerable degree of permanency. With this system of drainage, it is believed that the retaining walls can be dispensed with so as to admit of the change to sea-level, should it ever become necessary.

In the two-lake system, a saving of about $3,000,000 in the cost of four locks can be effected; about $4,000,000 in the Bohio dam; about $1,200,000 in the side walls of the Culebra Cut; about $1,000,000 in the extra excavation of the summit level: total, about $9,200,000. From this must be deducted the cost of excavating the summit from 85 to 65 feet, about $6,500,000; Alhajuela or Gamboa dam and appurtenances, about $2,500,000—a total of $9,000,000. The difference is so small as to be negligible; but if the canal be built without retaining walls in the Culebra Cut about $8,000,000 can be saved.

The two-lake project, as herein outlined, is practically the same as the one recommended by the Technical Commission to the Nouvelle Panama Compagnie as the best solution of the canal problem. It, therefore, has the approval of fourteen of the most eminent engineers of the civilized world.

In 1879, under the leadership of Ferdinand de Lesseps, the company known as the "Compagnie Universelle du Canal Interocéanique" was organized to build a sea-level canal at Panama. That company expended about $250,000,000 in the course of ten years and then went into bankruptcy. Under the laws of France, a liquidator was appointed by the court to take charge of its affairs. He appointed a Commission composed of French and foreign engineers. This Commission was known as the "Commission d'Etudes." It visited the Isthmus, made new surveys and studies of the canal project, and in 1890 submitted a report recommending a *canal with locks.*

In 1894, the Nouvelle Panama Compagnie was organized, with a view to investigating the canal project in all its engineering and commercial aspects. The new company called to its aid a Technical Commission, composed of fourteen engineers, drawn from all parts of the civilized world. Some of them were hydraulic engineers of great ability and world-wide reputation. Some had executed the largest canal projects that had ever been undertaken. This Commission, composed of the ablest engineers in the civilized world, after a prolonged and thorough investigation, recommended that the *sea-level project be abandoned* and that a canal be built *with locks.*

The Isthmian Canal Commission, composed of nine members, six of whom were engineers, was created in 1899 by the President under the authority of the River and Harbor Act, approved March 3, 1899. This Commission, after about two years of investigation, recommended a *canal with locks.*

It will thus be seen that, after the failure of the De Lesseps project for a sea-level canal, and after more thorough surveys and studies, no less than three Boards or Commissions, comprising among its members no less than thirty-one engineers, reported in favor of the *abandonment of the sea-level* project and the building of a *canal with locks.* They may all have been wrong in their conclusions, but the unanimous verdict of these thirty-one engineers, who gave years of study to the problem, should not be set aside, unless new and convincing evidence be found to justify the change. Has such evidence been discovered?

PETER C. HAINS.